Rb-Sr AGE DETERMINATION OF
THE CARBONACEOUS CHONDRITE "MURRAY".

by
ERNA BEISER

B.S., The City College of New York
(1961)

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF
SCIENCE
at the
MASSACHUSETTS INSTITUTE OF
TECHNOLOGY
January, 1964

Signature of Author

Department of Geology and Geophysics, January 20, 1964

Certified by

Thesis Supervisor

Accepted by
Chairman, Departmental Committee on Graduate Students
Rb-Sr AGE DETERMINATION OF

THE CARBONACEOUS CHONDRITE "MURRAY"

by

ERNA BEISER

Submitted to the Department of Geology and Geophysics on January 20, 1964, in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

The carbonaceous chondrite Murray was analyzed by the Rb-Sr method. The age obtained was $4.30 \pm 0.19 \times 10^9$ years. The decay constant used was $1.39 \times 10^{-11}$ years$^{-1}$. This age is within experimental error of the isochron determined for the stony meteorites. Thus, type II carbonaceous chondrites are cogenetic with stony meteorites; they do not represent primitive material nor the outer layer of an asteroidal parent body. The initial Sr isotopic ratio for $^{87}\text{Sr}/^{86}\text{Sr}$ used was $0.6980 \pm 0.001$.

Thesis Supervisor
Title

William H. Pinson Jr.
Associate Professor of Geology
TABLE OF CONTENTS

Abstract .................................................. 2
List of Tables ............................................... 4
List of Figures ............................................. 5
Acknowledgements ........................................... 6
Introduction ................................................ 7
Experimental Procedure .................................... 11
  Sample Preparation ....................................... 11
  Chemical Procedures ..................................... 12
  Mass Spectrometer Techniques ......................... 16
Results ..................................................... 17
Conclusions ............................................... 27
Appendix .................................................... 28
Bibliography ............................................... 30
**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rb and Sr Content of Murray</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Isotopic Composition of Murray</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>Isotopic Composition of Murray</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>Rb and Sr Blank Determination</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>Replicate Analyses of the SrCO₃ Standard</td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>Isotopic Composition of Murray</td>
<td>29</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Isochron of Pinson, et al. (1963) with data for &quot;Murray&quot; superimposed.</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>Two portions of Mass Spectrometer record.</td>
<td>27</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

The work was carried out in the Geochronology Laboratory in the Department of Geology and Geophysics at Massachusetts Institute of Technology, and was financially supported by the U. S. Atomic Energy Commission and the National Aeronautics and Space Administration. The author wishes to express appreciation and gratitude to Professors P. M. Hurley and W. H. Pinson, Jr. for financial support, use of the facilities, encouragement and advice.

The author is indebted to Mr. T. E. Krogh and Mr. R. H. McNutt for endless hours spent in encouragement, assistance and advice in the operation of the mass spectrometers. The author would like to thank Mr. R. M. Shields for assistance in perfecting the chemical procedure and Mr. R. H. Reesman for assistance and encouragement during the course of the investigation.

The author is indebted to Dr. E. P. Henderson of the U. S. National Museum, Washington, D. C. who supplied the sample of Murray that was used in this investigation.
**INTRODUCTION**

Carbonaceous chondrites contain more free carbon and more water and sulphur than the ordinary chondrites. Their bulk chemical composition, exclusive of volatiles and carbon compounds, is similar to that of the ordinary chondrites. Wiik (1956) has classified the carbonaceous chondrites into Types I, II, and III, based on their carbon, water, sulphur and metallic iron content:

\[
\begin{array}{cccccc}
\text{SiO}_2 & \text{MgO} & \text{C} & \text{H}_2\text{O} & \text{S} \\
\text{Type I} & 22.56 & 15.21 & 3.54 & 20.08 & 6.20 \\
\text{Type II} & 27.57 & 19.18 & 2.46 & 13.35 & 3.25 \\
\text{Type III} & 33.58 & 23.74 & 0.46 & 0.99 & 2.27 \\
\end{array}
\]

Further distinctions between the three types can be made on the basis of their known mineralogies. Type I carbonaceous chondrites contain no apparent chondrules. They have low densities (~2.2) and consist mainly of an amorphous, hydrous, layer-lattice-silicate (possibly chlorite and/or serpentine), magnetite, magnetic spinel, water-soluble sulphates, troilite, amorphous carbon, complex hydrocarbons, and free sulphur. Type II carbonaceous chondrites more closely resemble ordinary chondrites in texture. The chondrules consist chiefly of olivine and enstatite or
clinoenstatite. The chlorite-serpentine, olivine, pyroxenes, glass, troilite, and iron are imbedded in a groundmass that is opaque and amorphous. Type II densities range from 2.5 to 2.9. Much of the sulphur is in the free state. Type III carbonaceous chondrites are olivine-pigeonite chondrites. They are similar to Type II in texture. Their densities range from 3.4 to 3.5. Their main constituents are olivine, augite, clinoenstatite, magnetic spinel, orthopyroxene, chlorite-serpentine, troilite, plagioclase, iron, carbon and glass. Type I and Type II carbonaceous chondrites are extremely friable, thus they are never found as large stones.

Many theories on the origin of carbonaceous chondrites exist. Current theories all assume that they are accumulations of cosmic material that has been subjected to considerable alteration, dispersed, and possibly reaccumulated.

Urey (1961) proposed that carbonaceous chondrites can not be the parent material of the chondritic meteorites due to the chemical composition differences within each group. He postulates that the carbonaceous chondrites belong to the high iron group of chondrites with the addition of hydrogen sulphide, carbon compounds and water from outside sources.

Wood (1958, 1962) has postulated oxidation by CO2 and later by CO. Wiik (1956), Ringwood (1961), and Mason (1960) hold the view that the oxidized, hydrated material of the carbonaceous chondrites is primitive. This primitive material is hypothesized to have been altered to produce
olivine by a reduction and dehydration process. Fish, Gosses, and Anders (1960) and Anders (1963), have postulated that the asteroids are the parents of the meteorites and that the carbonaceous chondrites represent the outer layer of this parent body.

Patterson (1956) found an age of 4.55 ± 0.06 x 10^9 years for the Earth and meteorites from a study of Pb isotopes. Pinson, et. al. (1963) have shown, on the basis of Rb-Sr analyses, that an isochron yielding an age of 4.55 ± 0.20 x 10^9 years (A Rb = 1.38 x 10^{-11} years^{-1}) can be obtained from stony meteorites classified as "falls". Gast (1961, 1962) has published a similar result. This represents the time at which the chemical fractionation of the meteorite from the parent body took place. The chondrites apparently, since they lie on an isochron, have been closed systems with respect to Rb and Sr since this initial chemical fractionation.

If the carbonaceous chondrites represent the primordial material from which the stony meteorites were derived, the Rb-Sr age should be significantly greater than the 4.55 b.y. age obtained from the meteorite isochron and the Pb data. A significantly younger age should be obtained if the carbonaceous chondrites represent the outer layer of material of an asteroidal body. The carbonaceous chondrites should lie on the stony meteorite isochron if the carbonaceous chondrites were formed at the same time and from the same parent body, and thus would not be an anomalous group of objects, in
that respect.

This investigation represents an attempt at determining the Rb-Sr age of the Murray, Type II carbonaceous chondrite. Some of the conclusions reached by Pinson, et al. (1963) were used in interpreting the data. The investigation was undertaken in order to help shed some light on the theories of origin discussed above.
Sample Preparation

Eight pieces of Murray totalling thirty five grams were taken for analysis. Each contained a U. S. National Museum number (# 1769). The identifying numbers were removed from each piece with a carborundum grinding wheel. The surface of each sample was then cleaned of dust and clay with a wire rotating brush.

A stainless steel mortar and pestle and an agate mortar and pestle were used to pulverize and fine-grind the sample. The stainless steel mortar and pestle were cleaned first on a Dumore grinder mounted on a lathe and then washed with demineralized water and acetone. The agate hand mortar and pestle were cleaned with pumice, laboratory soap, demineralized water, 2N HCL, demineralized water and then acetone. An aluminum shield was made to fit over the agate hand mortar to prevent loss while grinding.

Before grinding operations were begun, the entire work surface was covered with a clean sheet of parafilm. The sample was coarsely broken up in the stainless steel mortar. Small amounts were then transferred to the agate mortar where they were finely ground. This finely ground portion was transferred to a clean, screw cap vial for storage. One of the eight original fragments was preserved.
Carbonaceous chondrites contain very small amounts of Rb and Sr, these elements being in the range of 1 to 2 ppm Rb and 10 to 12 ppm Sr. Thus, the contamination level must be kept as low as possible. In order to achieve this, various changes in the standard laboratory procedure (Herzog and Pinson, 1956; Herzog, et al., 1958; Faure and Hurley, 1962) have been effected.

Wasserburg (1963) has shown that strontium contamination occurs from the use of laboratory or pyrex glassware. This contamination is not picked up in the blank experiments and seems to occur only when mineral samples are used. Seemingly it is the contact of the hot solution containing the analysis sample with the glassware that causes the leaching out of the strontium. Thus, the steps in which solutions are evaporated or residues ignited, in pyrex beakers seem to produce significant amounts of contamination. To eliminate this source of contamination polypropylene beakers have been substituted for pyrex beakers. Previously, the residue obtained from the ion exchange column was ignited in a 5 ml pyrex beaker. Due to the possibility of contamination at these high temperatures, 5ml fused quartz crucibles, obtained from the Thermal American Fused Quartz Company, have been used.
Vycor ion exchange columns were used in place of pyrex. Fused quartz wool was used to keep the ion exchange resin confined in the bottom of the column. Vycor capillary tips are used to place the prepared sample on the mass spectrometer filament. In fact, the use of pyrex glassware was entirely eliminated from the operation of preparing samples for the mass spectrometer.

In the dissolution procedure, four types of acid and water are used. The water is distilled, demineralized and then vycor distilled. The HCl and HNO₃ used are distilled in vycor stills from reagent grade HCl and HNO₃. The HClO₄ used is commercially double distilled in vycor and shipped in vycor ampules from the G. Frederick Smith Chemical Company. HF was purified by Robert M. Shields by using a polyethylene tubing and teflon bubbling apparatus with vycor distilled water. 30.5 N HF was prepared in this manner.

In the dissolution of the carbonaceous chondrite an insoluble black residue is formed. This residue must be separated before putting the solution on to the ion exchange column. The separation was affected by centrifuging at high speed in a vycor centrifuge tube.

As a further precaution against contamination, the entire work area around the ion exchange columns was covered with plastic sheeting. An aluminum cover was put over the hot plate and the inside covered with teflon tape. However, numerous experiments by other workers in the laboratory have
demonstrated that laboratory fallout of Rb and Sr is a negligible source of contamination for these elements in chondrite analysis work.

One and a half to two gram samples were weighed out on a Mettler balance and placed in platinum crucibles. A small amount of water and 6N HCl were added and the samples were allowed to stand overnight. It is thought that this step aids in dissolution for the olivine is readily attacked by this acid.

Dilute Rb\textsuperscript{87} and Sr\textsuperscript{86} were added by pipette to each sample. Extensive calibration work has been done on the spike and shelf solutions. (Pinson, 1962). The Rb\textsuperscript{87}/Sr\textsuperscript{86} ratio is quite sensitive to changes in the spike and shelf solutions, and to a knowledge of the isotopic composition of these solutions.

After the addition of the spikes to each sample, approximately 30 ml HF and 3 ml HClO\textsubscript{4} were added. The samples are then placed on a steam bath, allowed to digest with frequent stirring by a teflon rod. When this portion of HF has evaporated, another portion is added, and again evaporated with constant stirring. As perfect a solution as possible was obtained by adding measured quantities of 2N HCl and water with constant stirring. It is important to obtain perfect equilibration between sample and spike, and it is thought that this was attained from the clearness of the solutions in each case. The sample is then removed from the
steam bath and allowed to cool. Sr$^{85}$ and Rb$^{84}$ carrier-free, radioactive tracers were added. The sample was then transferred to vycor centrifuge tubes, and centrifuged for several minutes. The supernatant was poured off and placed on the ion exchange columns.

The vycor ion exchange columns are approximately 2.5 cm. by 60 cm. and are about half filled with Dowex 50W-X8 resin. This is a strongly acidic cation exchange resin with 8% cross-linkage, and a mesh size of two to four hundred.

The column was eluted with 2N HCl and monitored with a scintillation counter. The Rb and Sr fractions were collected in 20 to 30 ml portions in the 100 ml polypropylene beakers. For both Rb and Sr, the beakers containing the highest activity of Rb$^{84}$ and Sr$^{85}$ were combined, evaporated down and transferred to a 5 ml fused quartz crucible which contained a few mls of HClO$_4$. The beakers were placed on a hot plate, evaporated to dryness, and ignited over a Tyrell burner to remove the excess HClO$_4$. A few mls of HNO$_3$ were then added and the beaker was again taken to dryness. This last step was repeated. The sample was then ready to be placed on the mass spectrometer filament or to be stored for future use.

Along with each group of isotope dilution analyses, a set of Sr and Rb blanks were run. These blanks were treated in the same manner as the sample.
For Sr isotope ratio analyses, a three gram sample was weighed out. The dissolution procedure was the same but no Rb or Sr spikes were added.

**Mass Spectrometer Techniques**

The mass spectrometer used was standard 6-inch radius, 60° sector, solid source, single collector, Nier type machine. It was designed and built at M. I. T. The ion current was amplified by a vibrating reed electrometer and peaks recorded on a Brown Strip Chart Recorder. The low pressures necessary for operating were obtained by a forepump in series with a mercury diffusion pump. The filament was tantalum ribbon that is spot welded to the posts of the source. All the filaments were proven clean of the analysis element in the mass spectrometer, before application of the sample.

The sample is placed on the filament by means of a vycor capillary tip. It is put on in the form of a nitrate and slowly evaporated to dryness.
RESULTS

The analytical results obtained in this thesis investigation are shown in Tables 1 - 6. Replicate isotope dilution analyses were made for rubidium and strontium. Rubidium and strontium blank determinations were made along with the isotope dilution analyses.

The elemental content of Murray, on the basis of triplicate analyses, are $1.67 \pm 0.027$ ppm Rb; $11.05 \pm 0.029$ ppm Sr, the precision being expressed as the standard deviation of the mean. These isotope dilution values have all been corrected for blank contamination, which in all cases were almost negligibly small, as shown in Table 4. The Rb/Sr weight ratio was converted to $\text{Rb}^{87}/\text{Sr}^{86}$ atomic ratio.

A value for the isotopic composition was determined from a mass spectrometric run of 78 sets, and, by our laboratory standards, was of the very highest quality. A portion of the mass spectrometric record is reproduced in Figure 2. The value obtained was $0.7249 \pm 0.0005$. Correcting this value for contamination, a value of $0.7250 \pm 0.0005$ was obtained, demonstrating again the near negligibility of contamination.

On the basis of two mass spectrometric runs of 18 sets apiece, a value of $0.7254 \pm 0.002$ was obtained. Although the runs were of poor quality, this value lies within experimental error of the value obtained from the run of high precision.
The standard SrCO₃ (Eimer and Amend, Lot # 492327) was used as an interlaboratory standard and to test the precision of the isotope ratio determinations for the Murray meteorite. A value of \( \frac{\text{Sr}^{86}}{\text{Sr}^{87}} \) ranging from 0.708 to 0.709 is reported by Faure and Hurley, 1963; and Pinson, et al. 1963. This standard was run during the course of the Murray Sr isotope ratio analyses, with the results shown in Table 6. These values were well within the values reported by several other laboratories.

The \( \frac{\text{Sr}^{86}}{\text{Sr}^{87}} \) ratios were corrected for isotopic fractionation by assuming that the \( \frac{\text{Sr}^{86}}{\text{Sr}^{88}} \) ratio is a constant and equal to 0.1194. The normalization of the \( \frac{\text{Sr}^{86}}{\text{Sr}^{87}} \) ratio is achieved by applying half of the factor necessary to adjust the \( \frac{\text{Sr}^{86}}{\text{Sr}^{88}} \) ratio to 0.1194 to the \( \frac{\text{Sr}^{87}}{\text{Sr}^{86}} \) ratio. This normalization procedure has been adequately justified by Faure (1961) and Faure and Hurley (1963).

The age formula for the Rb-Sr method is:

\[
\frac{\text{Sr}^{87}}{\text{Sr}^{86}}_p - \frac{\text{Sr}^{87}}{\text{Sr}^{86}}_i = \frac{\text{Rb}^{87}}{\text{Sr}^{86}} \left( e^{\lambda_{\text{Rb}} t} - 1 \right)
\]

where \( \frac{\text{Sr}^{87}}{\text{Sr}^{86}}_p \) is present, measured ratio; \( \frac{\text{Sr}^{87}}{\text{Sr}^{86}}_i \) is the initial ratio; \( \frac{\text{Rb}^{87}}{\text{Sr}^{86}} \) is the atomic ratio; \( t \) is the age; \( \lambda_{\text{Rb}} \) is the decay constant for Rb⁸⁷. Aldrich (1956) reported a half-life for Rb⁸⁷ of 50 ± 2 x 10⁹ years.
The corresponding decay constant is $1.396 \times 10^{-11}$ years$^{-1}$.

A value of $1.39 \times 10^{-11}$ years$^{-1}$ was used in the meteorite analyses in order to directly compare the results obtained from the Rb-Sr isochron (Figure 1) with Patterson’s Pb age of 4.55 b.y. for the Earth and Meteorites. The initial Sr$^{87}$/Sr$^{86}$ ratio was assumed to be $0.6990 \pm 0.001$ on the basis of the work of Pinson, et. al., 1963.

An age of $4.30 \pm 0.19 \times 10^9$ years was obtained using the data found in Tables 1 and 2.
### TABLE 1

**Rb and Sr Content of Murray**

<table>
<thead>
<tr>
<th>Rb (ppm.wt)</th>
<th>Sr (ppm.wt)</th>
<th>Rb$^{87}$/Sr$^{86}$ (atomic ratio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.70</td>
<td>11.07</td>
<td>0.4455</td>
</tr>
<tr>
<td>1.70</td>
<td>10.99</td>
<td>0.4487</td>
</tr>
<tr>
<td>1.62</td>
<td>11.08</td>
<td>0.4241</td>
</tr>
</tbody>
</table>

**Average**

<table>
<thead>
<tr>
<th>Rb (of the mean)</th>
<th>Sr (of the mean)</th>
<th>Rb$^{87}$/Sr$^{86}$ (of the mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1.67$</td>
<td>$11.05$</td>
<td>$0.4394$</td>
</tr>
<tr>
<td>$\pm 0.027$</td>
<td>$\pm 0.029$</td>
<td>$\pm 0.0077$</td>
</tr>
<tr>
<td>$\pm 1.61%$</td>
<td>$\pm 0.26%$</td>
<td>$\pm 1.75%$</td>
</tr>
</tbody>
</table>
TABLE 2

Isotopic Composition of Murray
(Mass spectrometer run of 78 sets)

<table>
<thead>
<tr>
<th>( ^{86}\text{Sr}/^{88}\text{Sr} )</th>
<th>( ^{87}\text{Sr}/^{86}\text{Sr} )</th>
<th>( ^{87}\text{Sr}/^{86}\text{Sr} ) (normalized to 0.1194)</th>
<th>( ^{87}\text{Sr}/^{86}\text{Sr} ) (corrected for Sr contamination)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1194</td>
<td>0.7249</td>
<td>0.7249</td>
<td>0.7250</td>
</tr>
</tbody>
</table>

\[ \overline{\sigma} \text{ (of the mean)} \pm 0.0005 \]
\[ \overline{E} \text{ (of the mean)} \pm 0.02\% \]

\[ t \text{ calculated} = 4.30 \pm 0.19 \times 10^9 \text{ years.} \]

\[ (\lambda_{\text{Hb}} = 1.38 \times 10^{-11} \text{ years}^{-1}) \]
TABLE 3
Isotopic Composition of Murray
(Two Mass Spectrometer Runs of 18 sets each)

<table>
<thead>
<tr>
<th>Sr$^{86}$/Sr$^{88}$</th>
<th>Sr$^{87}$/Sr$^{86}$</th>
<th>Sr$^{87}$/Sr$^{86}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(measured)</td>
<td>(measured)</td>
<td>(normalised to 0.1194)</td>
</tr>
<tr>
<td>0.1188</td>
<td>0.7256</td>
<td>0.7236 6.02x10^{-4} 0.09%</td>
</tr>
<tr>
<td>0.1180</td>
<td>0.7308</td>
<td>0.7270 19.03x10^{-4} 0.26%</td>
</tr>
</tbody>
</table>

Averages

| 0.1184 | 0.7282 | 0.7253 2x10^{-3} 0.28\% |

0.7254
(corrected for Sr contamination)
<table>
<thead>
<tr>
<th></th>
<th>Rb</th>
<th>Sr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(µg/mg)</td>
<td>(µg/mg)</td>
</tr>
<tr>
<td>Rb</td>
<td>0.026</td>
<td></td>
</tr>
<tr>
<td>Sr</td>
<td></td>
<td>0.071</td>
</tr>
</tbody>
</table>
TABLE 5
Replicate Analyses of the SrCO₃ Standard

(Eimer & Amend Lot #492327)

<table>
<thead>
<tr>
<th></th>
<th>86/88 (measured)</th>
<th>87/86 (measured)</th>
<th>87/86 (normalized to 0.1194)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1186</td>
<td>0.7105</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1202</td>
<td>0.7060</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1191</td>
<td>0.7094</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.1179</td>
<td>0.7119</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7080</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7083</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7084</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.7074</td>
<td></td>
</tr>
</tbody>
</table>
Figure 1

Isochron of Pinson, et al. (1963) with data for Murray superimposed.

$\left(\frac{\text{Sr}^{87}}{\text{Sr}^{86}}\right)_0 = 0.698 \pm 0.001$

$T = 4.28 \times 10^9 \text{ YRS.}$  \hspace{1cm}  $\lambda_{\text{Rb}} = 1.47 \times 10^{-11} \text{ YR.}^{-1}$

$T = 4.55 \times 10^9 \text{ YRS.}$  \hspace{1cm}  $\lambda_{\text{Rb}} = 1.38 \times 10^{-11} \text{ YR.}^{-1}$
Figure 2

Two portions of Mass Spectrometer record, for Murray unspiked Sr analysis.
CONCLUSION

The age of $4.30 \pm 0.19 \times 10^9$ years obtained for the carbonaceous chondrite Murray indicates that Type II carbonaceous chondrites appear to be cogenetic with stony meteorites — i.e., they lie within experimental error of the isochrons reported by Gast (1961, 1962) and Pinson, et. al. (1963). The isochron of Pinson, et. al. is reproduced in Figure 1 with the data for Murray superimposed on it.

Within the error limits assigned to the age of Murray, and Pinson's isochron, the hypothesis that carbonaceous chondrites represent the outer layer (which differentiated at a later date) of a parent asteroidal body (DuFresne and Anders, 1961; Anders, 1963) remains a possibility.

At the present status of this work, and because of the possibility of further refining the stony meteorite isochron, the hypothesis that the carbonaceous chondrites are the primitive material from which the stony meteorites are derived, is still a possibility.

However, comparing the Rb-Sr age of $4.30 \pm 0.19 \times 10^9$ years with Patterson's Pb age of $4.55 \pm 0.06 \times 10^9$ years, it seems highly unlikely that the Type II carbonaceous chondrites, such as Murray, are older. Thus, the Rb-Sr data is rather strong evidence that the Type II carbonaceous chondrites are not the primitive material from which the stony meteorites were derived.
APPENDIX

Values of 0.7204 and 0.7192 were calculated from two of the isotope dilution analyses (Table 6). An initial Sr\textsuperscript{87}/Sr\textsuperscript{86} ratio of 0.6980 (Pinson, et. al. 1963) was assumed. These calculations were made to serve as an estimate of what the measured isotopic composition would be. The calculated value would have more significance if a Sr\textsuperscript{84} spike had been used in addition to a Sr\textsuperscript{86} spike, thus enabling a correction for instrumental fractionation to be made. In addition, the use of the above initial Sr\textsuperscript{87}/Sr\textsuperscript{86} ratio is unjustified if the carbonaceous chondrites do not lie on the isochron obtained from the stony meteorites. In calculating the age of the carbonaceous chondrite, only the value obtained from the unspiked mass spectrometer runs was used.
### TABLE 6

Isotopic Composition of Murray
(calculate from Isotope Dilution Analyses)

<table>
<thead>
<tr>
<th>Sr$^{86}$/Sr$^{88}$</th>
<th>Sr$^{87}$/Sr$^{86}$</th>
<th>Sr$^{87}$/Sr$^{88}$</th>
<th>Sr$^{87}$/Sr$^{86}$</th>
<th>Scans</th>
</tr>
</thead>
<tbody>
<tr>
<td>(measured)</td>
<td>(measured)</td>
<td>(measured)</td>
<td>(calculated)</td>
<td></td>
</tr>
<tr>
<td>0.3286</td>
<td>0.3307</td>
<td>0.1086</td>
<td>0.7204</td>
<td>134</td>
</tr>
<tr>
<td>0.3385</td>
<td>0.2960</td>
<td>0.1150</td>
<td>0.7192</td>
<td>96</td>
</tr>
</tbody>
</table>

Assumed Sr$^{87}$/Sr$^{86}$ initial ratio = 0.6980
BIBLIOGRAPHY


Farrington, O. G. (1915), Meteorites, their structure, composition, and terrestrial relations. Publ. by the author.


